Multi-Band Uncooled Radiometric Imager (MURI) Airborne Flight Test Status

NASA ESTO - Instrument Incubator Program

PI: Phil Ely - Leonardo DRS

CoIs: Aaron Gerace - Rochester Institue of Technology

Ray Wagoner - Leonardo DRS

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Problem to Solve with Uncooled Radiometer

- Thermal Imaging from a Space Platforms such the TIRS Instrument on LANDSAT have historically used Cooled FPA Technology requiring Cryocooling to temperatures as cold as 43K. Cryocoolers require significant size, weight and power and space rated coolers must be selected to ensure reliability for a long mission life.

- With MURI, DRS is leveraging proven Uncooled Microbolometer FPA Technology, operating at room temperature, to demonstrate land Imaging on an airborne platform.

- 1) Microbolometers have a long time constant, which can result in image smearing with a satellite orbiting at ~7km/sec over the ground; 2) There is no cold shielding with microbolometers as is used with cooled FPAs, and radiometric accuracy can be impacted significantly by small changes in instrument temperature; 3) Radiometers use relatively narrow spectral bands (~1um wide) reducing the sensitivity of microbolometers, which typically image in a broader spectral band (8-14um).

- Developing an instrument solution that can utilize microbolometers and overcome the limitations discussed in the previous bullet would very significantly reduce the size, weight, power and cost of a spaceborne instrument for land imaging.

MURI Instrument Challenges Using Bolometers

3 Major Challenges Being Addressed on DRS' IIP MURI Program Using Microbolometers for Earth Imaging from Low Earth Orbit

Issue #1: Long time constant of microbolometers make them susceptible to image smear when imaging from LEO satellites travelling @ ~7km/sec or aircraft flying at 125 Knots

Solution: Implement piezo backscan of FPA to precisely match the image velocity on the FPA and hence stabilize image (i.e. eliminate image smear)

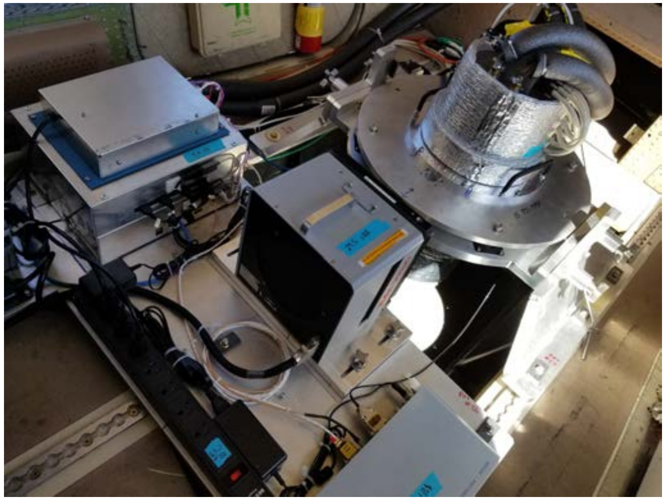
Issue #2: Bolometer FPAs are sensitive to temperature of their surrounding environment (lens temp, camera housing temp, etc.) making achieving a radiometric accuracy of < 2% challenging.

Solution: Stabilize and control the lens and focal plane assembly temperatures, and utilize DRS' proprietary TCOMP algorithms to radiometrically correct the FPA output data for FPA and Lens Temperature Changes in real time.

Issue #3: NETD of bolometers are degraded when used with the narrow spectral band filters

Solution: Maintain use of f/1 optics, fabricate bolometers with an even longer time constant (~20msec) to get a 40% improvement in NETD and then frame stack 14 stabilized frames to improve NETD further.

MURI Program Overview



MURI Airborne Sensor

Band	Center Wavelength (um)	Spectral Bandwidth (um)	Application
1	7.65	0.111	Methane Monitoring
2	8.55	0.370	SO_2, cloud/volcanic ash properties
3	8.94	0.371	Minerals, SO_2
4	10.07	0.491	Surface temperature, vegetation, minerals
5	10.88	0.634	LANDSAT 8 TIRS 1
6	11.94	1.005	LANDSAT 8 TIRS 2

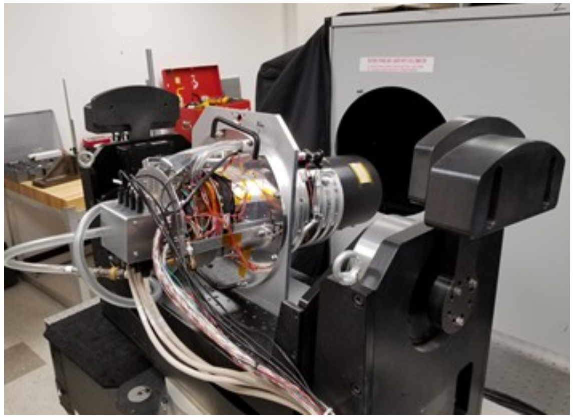
6 Spectral Bands as Built

TRL at Start of Program = 3
TRL Now = 5
TRL at Completion of Program = 6

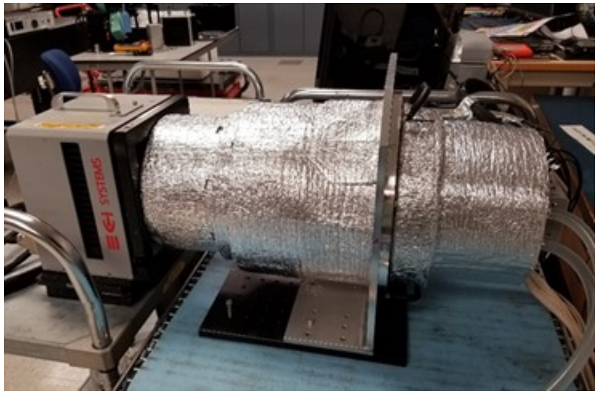
- DRS uses a Piezo Stage to Backscan a 6-Band Multispectral Uncooled Radiometer Imager (MURI) to achieve NETD and RER performance consistent with LANDSAT
- In Flight Absolute Radiometric Precision of <2% was achieved by controlling FPA & Lens Temp and then monitoring the Lens and Camera Housing Temp and correcting the radiometry using DRS patented TCOMP algorithms
- Two Flight Data Collects Completed, another one planned, all are LANDSAT 8 Under-flights:
  - The first (8/19) and Second (10/19) assessed image quality and radiometric accuracy of known targets deployed (Landsat Truth data) in Northern and Southern California
  - The third flight test (10/20) will use higher sensitivity bolometers to look at various ground and water targets of known temperature and emissivity
- Design and benchtop demo 6U Cubesat Sensor Subsystem Variant of MURI with Piezo Launch lock, scheduled to complete by 1/21.

Overview of MURI Flight Instrument Hardware

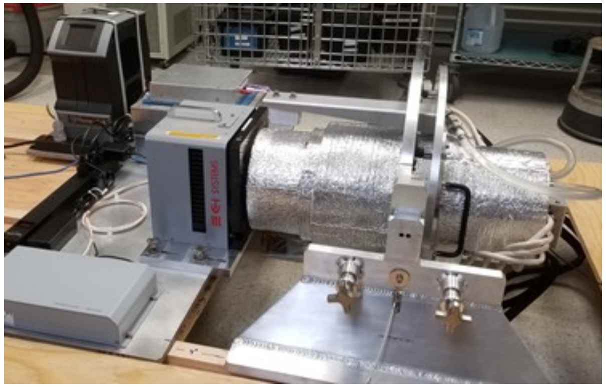
RER Testing with Rotary Stage and Collimator (5/2019)



NEDT Testing and Radiometric Calibration with Blackbody (7/2019)

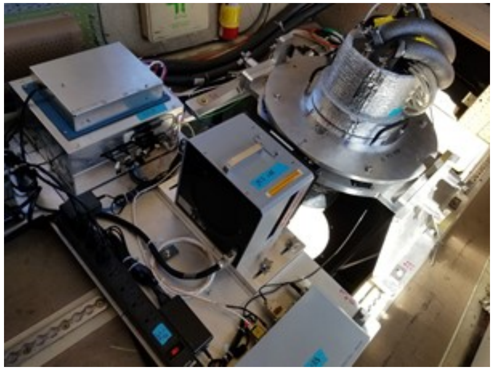


System Aircraft Mounting Lab Mockup (8/2019)



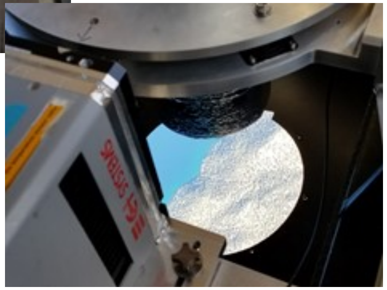
Flight Testing (Aug-Oct 2019)

Installed on DHC-6



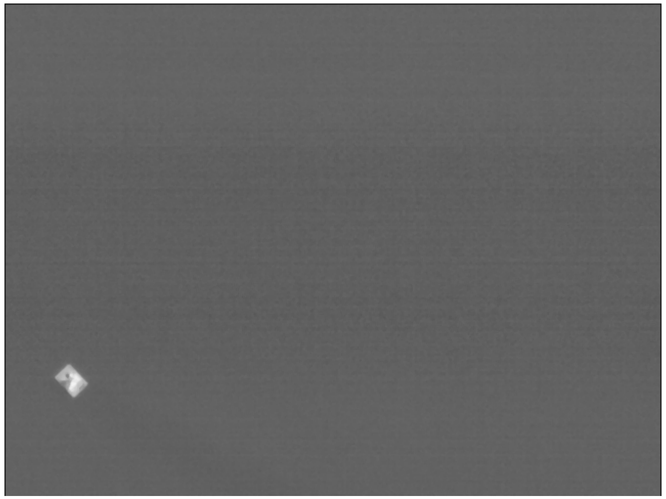
Inflight Calibration

Data Collect



Flight Test Imagery - Various Data Collects

Salton Sea Buoy

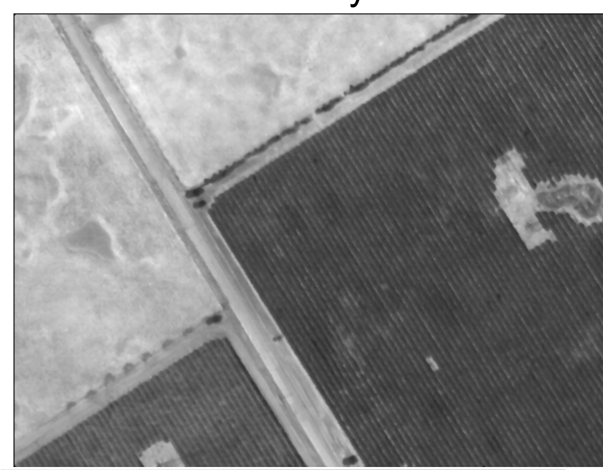


Eldorado Park Lake
Band 5 Stacked
and Stitched

Russell Ranch

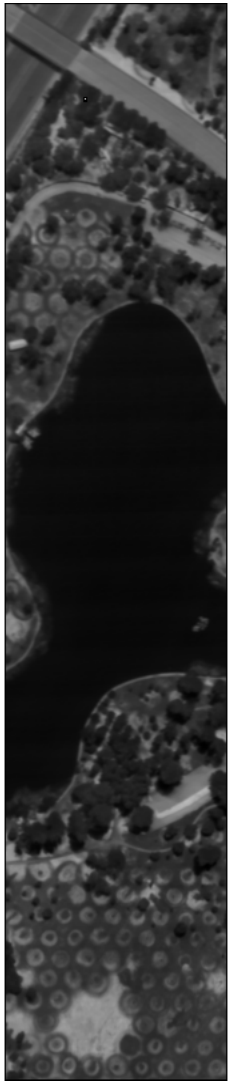
Hotel Pool/Spa

Lodi Vineyard

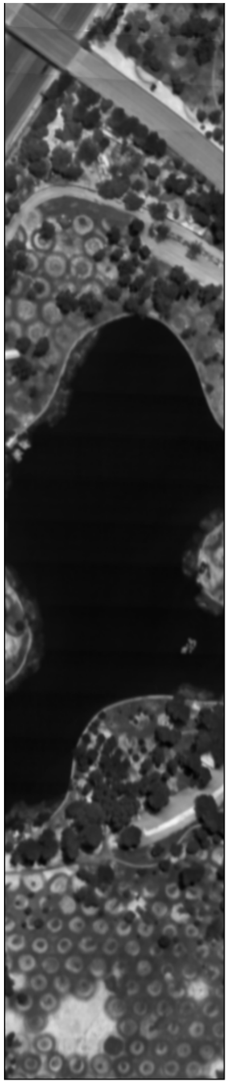


El Dorado Lake Park – Long Beach (5 LWIR Spectral Bands)

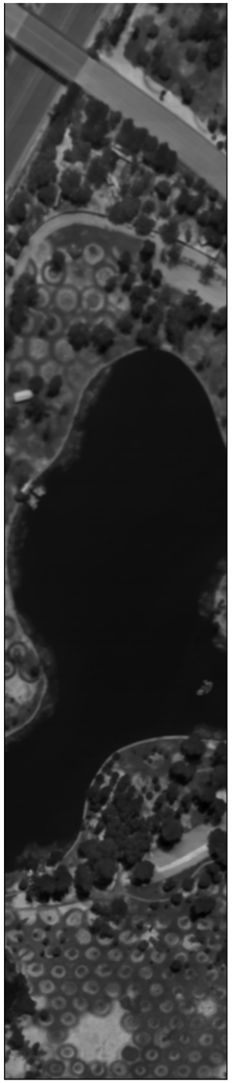
Band 2 - 8.55um



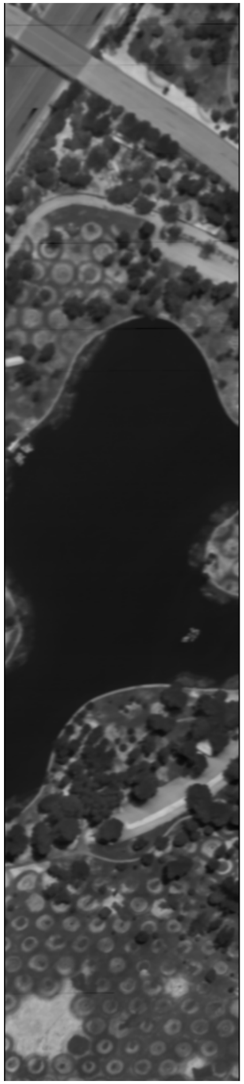
Band 3 - 8.94um



Band 4 - 10.07um



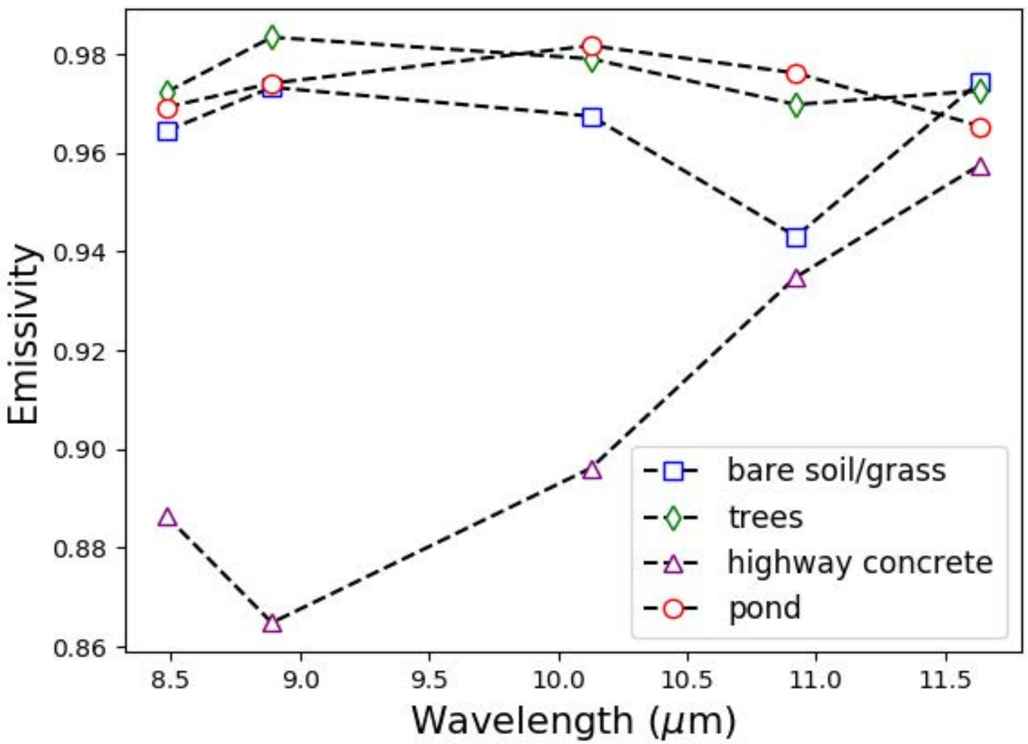
Band 5 - 10.88um



Band 6 - 11.94um

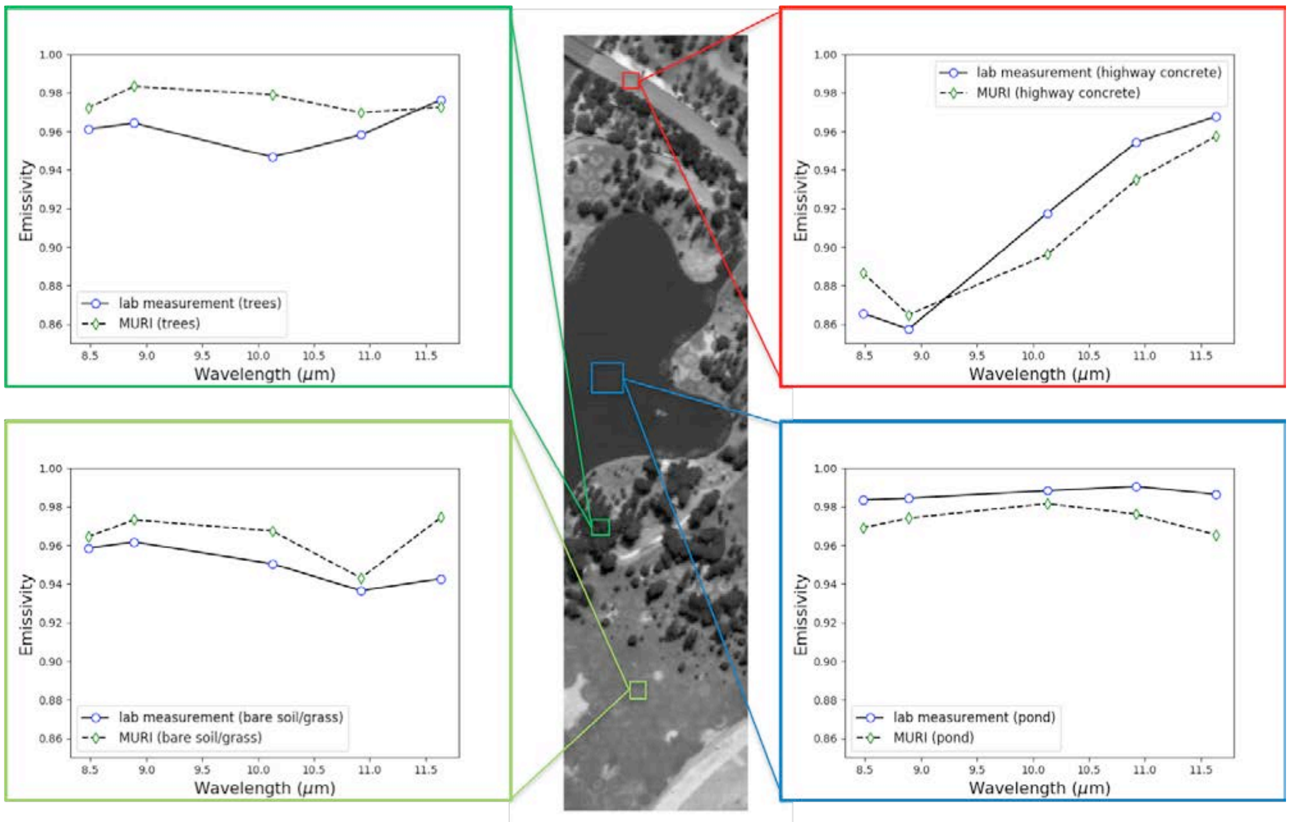
Multiband Imaging Advantages

- Temperature emissivity separation (TES).
  - With five bands from 8 – 12 microns, TES becomes an attractive option.
  - Chose ROI’s over four materials in the Eldorado park area.
  - Were able to retrieve emissivity-estimates for the four materials.



Multiband Imaging Advantages

- Lab-measured band-effective emissivities were acquired for comparison to TES-derived emissivities.
  - Note that we arbitrarily chose the spectral emissivities based on material type.



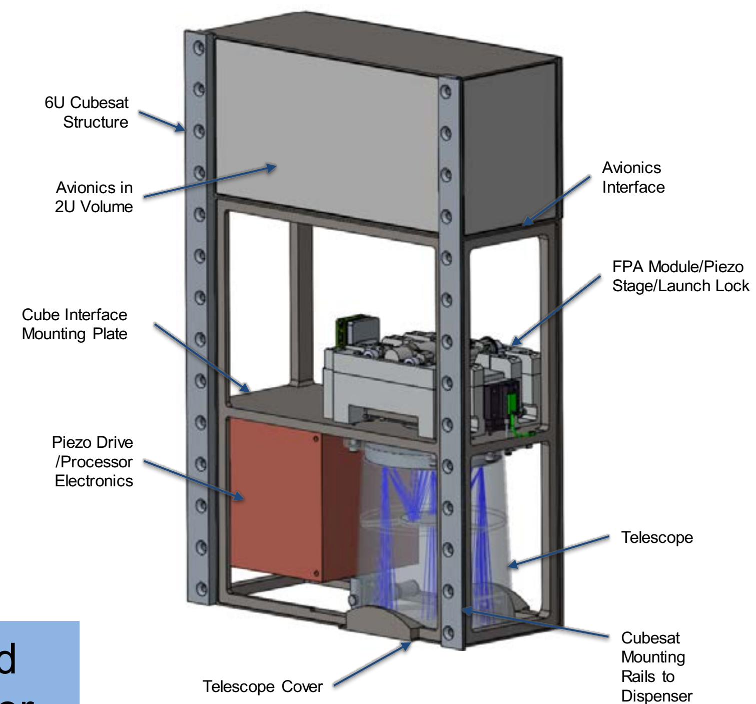
Remaining Work to Accomplish This Year on MURI

- Perform Radiation Testing (TID and SEU/SEL) of Uncooled FPAs at TAMU (8/20) – Delayed because of COVID19.

- Complete third airborne flight test with higher sensitivity bolometer arrays (10/20).

- Further evaluate accuracy of emissivity versus wavelength curves for various ground targets, using spectral ground truth data from 3rd Airborne test (11/20).

- Complete 6U compatible Radiometer Sensor Design, CDR in June 2020 and fabrication and lab test by 1/21.



DRS Thanks NASA ESTO for the Opportunity to Build and Demonstrate a Prototype Uncooled Multi Band Radiometer Imager for Future Earth Imaging Payload Applications